

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Benjamin GEBHART

Serial No.: Not yet assigned

Filing Date: March 6, 2002

Title: **NUCLEATE BOILING SURFACES FOR COOLING AND GAS GENERATION**

PRELIMINARY AMENDMENT

Commissioner for Patents  
Washington, D.C. 20231

Sir:

Before action in this application and before calculation of the filing fee, please amend the application as follows:

IN THE SPECIFICATION

Please amend the specification at page 1, lines 1-7 to replace the paragraph describing the claim to priority with a new paragraph as indicated in the clean copy found in Appendix 1 of this Preliminary Amendment.

IN THE CLAIMS

Please cancel claims 1, 3-4, 6-7, 9, and 34-36, which were allowed as amended in U.S. Patent Application No. 08/485,161, without prejudice or disclaimer of the subject matter therein.

Please amend claims 2, 5, and 8 as indicated in the "mark-up" copy found in Appendix 2 of this Preliminary Amendment. A "clean"

copy of all pending claims, in compliance with 37 C.F.R. §1.121, may also be found in Appendix 3 of this Preliminary Amendment.

Please add new claim 37, as shown in the "clean" copy of all pending claims found in Appendix 3 of this Preliminary Amendment.

**REMARKS**

The Specification has been amended at page 1, lines 1-7, to replace the existing paragraph describing claims to priority with a new, updated paragraph. A "clean" copy of the replacement paragraph is found in Appendix 1. The Specification has been amended to insert a claim to priority to the parent application of this Divisional application.

Claims 1, 3-4, 6-7, 9, and 34-36 have been canceled, and claims 2, 5, and 8 have been amended. A "markup" copy of the amended claims is found in Appendix 2. New claim 37 has been added. A "clean" copy of all pending claims, including the amended and new claims, is found in Appendix 3.

Upon entry of the above amendments, claims 2, 5, 8, 10-33, and 37 are pending in the application. The amendments do not introduce new matter within the meaning of 35 U.S.C. §132. Canceled claims 1, 3-4, 6-7, 9, and 34-36 were allowed, as amended, in U.S. Patent Application No. 08/485,161. Claims 2, 5, and 8 have been amended to make claim 2 independent and adjust claim dependency

accordingly. New claim 37 has been added to specifically cover a preferred embodiment. Basis for the amendments is found at page 8, line 23 to page 25, line 25; in claims 2, 5, 8, 10-33 as originally filed; and elsewhere throughout the specification and claims. Accordingly, the Examiner is respectfully requested to enter the above amendments before examination.

The Examiner is welcomed to telephone the undersigned attorney if (s)he has any questions or comments.

Respectfully submitted,

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Date: March 6, 2002

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**Appendix 1**

Amendments to the Specification: clean copy (37 C.F.R. §1.121(b)(1)).

Please amend the specification by deleting the text at page 1, lines 1-7, and replacing it with the following:

"This application is a Divisional Application of U.S. Patent Application No. 08/485,161, filed June 7, 1995, which in turn is a continuation application of U.S. Patent Application No. 07/767,227, filed on September 27, 1991, and now abandoned, which in turn is a continuation-in-part application of U.S. Patent Application 07/529,787, filed on May 25, 1990, and now abandoned, which in turn is a continuation application of U.S. Patent Application 07/409,980, filed on September 18, 1989, and now abandoned, which in turn is a continuation application of 07/159,713, filed on February 24, 1988, and now abandoned., the entire contents of which are hereby incorporated by reference in its entirety."

**Appendix 2**

Amendments to pending claims: mark-up copy (37 C.F.R. §1.121(c)(1)(ii)).

Please cancel claims 1, 3-4, 6-7, 9, and 34-36 without prejudice or disclaimer of the subject matter expressed therein.

Please amend claims 2, 5, and 8 as follows:

2. (Once amended) A method of cooling a surface by nucleate boiling, comprising:

polishing said surface;

photo etching said surface to obtain a predetermined minimum surface density of discrete nucleation sites having a conical cross-section tapering to at least a minimum predetermined depth;

immersing said surface in a refrigerant having a preselected boiling point so that said nucleation sites become substantially flooded by said refrigerant; and

permitting said surface to heat up to a temperature of at least said preselected boiling point, said heating initiating nucleate boiling of said refrigerant without a temperature overshoot on the initial ascent [The method of claim 1],

wherein said conical cross-section has a cavity cone

angle,  $\theta$ , which is greater than the liquid contact angle,  
 $\gamma$ , of said refrigerant.

5. (Once amended) The method of claim 2 [1], wherein said  
refrigerant has a liquid contact angle of less than about  $5^\circ$ .

8. (Once amended) The method of claim 2 [1], wherein said  
nucleate boiling initiates with a reversal of trend of less than  
about  $2^\circ\text{C}$ .

**Appendix 3**

All pending claims (claims 2, 5, 8, 10-33, and 37): clean copy  
(37 C.F.R. §1.121(c)(3)).

2. (Once amended) A method of cooling a surface by nucleate  
boiling, comprising:

polishing said surface;

photo etching said surface to obtain a predetermined minimum  
surface density of discrete nucleation sites having a conical  
cross-section tapering to at least a minimum predetermined depth;

immersing said surface in a refrigerant having a preselected  
boiling point so that said nucleation sites become substantially  
flooded by said refrigerant; and

permitting said surface to heat up to a temperature of at  
least said preselected boiling point, said heating initiating  
nucleate boiling of said refrigerant without a temperature  
overshoot on the initial ascent,

wherein said conical cross-section has a cavity cone  
angle,  $\theta$ , which is greater than the liquid contact angle,  
 $\gamma$ , of said refrigerant.

5. (Once amended) The method of claim 2, wherein said  
refrigerant has a liquid contact angle of less than about  $5^\circ$ .

8. (Once amended) The method of claim 2, wherein said nucleate boiling initiates with a reversal of trend of less than about 2°C.

10. A method of cooling an electronic component having at least one electronic chip means thereon, comprising:

photo etching a back surface of said chip means to provide thereon a predetermined minimum surface density of discrete, nucleation sites, each having a conical cross-section tapering to at least a minimum predetermined depth;

immersing said back surface of said chip in a refrigerant having a preselected boiling point so that said nucleation sites become substantially flooded by said refrigerant;

operating said electronic component so that said back surface of said chip is heated to at least said boiling point, said heating initiating nucleate boiling of said refrigerant without a temperature overshoot on the initial ascent.

11. The method of claim 10, wherein said nucleation sites comprise spaced reverse-pyramidal cavities lying substantially on the same plane and having a first dimension of less than about 10µm.



12. The method of claim 11, wherein said nucleation sites include a spacing of less than about 60 $\mu$ m.

13. The method of claim 11, wherein said nucleation sites include a spacing of less than about 40 $\mu$ m.

14. The method of claim 11, wherein said nucleation sites include a spacing of less than about 20 $\mu$ m.

15. The method of claim 10, wherein said back surface contains a mirror-polished region including a plurality of nucleation sites having substantially the same geometric configuration.

16. The method of claim 12, wherein said nucleation sites comprise inverted square pyramids having a side dimension of at least about 10 $\mu$ m and a depth greater than 5 $\mu$ m.

17. A heat transfer system, comprising:

a heat transfer surface including a minimum surface density of discrete, nucleation sites having a conical cross-section tapering to a minimum predetermined depth;

a refrigerant having a preselected boiling point disposed in contact with said surface so as to substantially flood said

nucleation sites, said nucleation sites permitting nucleate boiling of said refrigerant without a temperature overshoot on the initial ascent.

18. The system of claim 17, wherein said conical cross-section includes a cavity cone angle,  $\theta$ , which is greater than the liquid contact angle,  $\gamma$ , of said refrigerant.

19. The system of claim 17, wherein said minimum predetermined depth is greater than about  $3\mu\text{m}$  and a significant portion of said sites have an aspect ratio greater than about .3.

20. The system of claim 17, wherein nucleation sites include a spacing of less than about  $60\mu\text{m}$ .

21. The system of claim 17, wherein said nucleation sites comprise reverse-pyramidal cavities.

22. The system of claim 17, wherein said nucleate boiling occurs by a plurality of bubbles exiting said sites substantially independently from a wake of a neighboring bubble.

23. The system of claim 17, wherein said nucleation sites are spaced a minimum distance apart so that flooding of said sites by

said refrigerant is substantially independent of neighboring departing bubbles.

24. The system of claim 17, wherein a substantial portion of said nucleation sites are about the size of a vapor embryo remaining after sites have become substantially flooded.

25. An electronic component cooling system comprising the heat transfer system of claim 17, whereby the refrigerant is boiled on said surface to cool said component.

26. A gas generation system comprising the heat transfer system of claim 17, whereby said refrigerant is boiled to form said gas.

27. A heat transfer system including an electronic component, comprising:

a chip including a back surface having thereon a region which has been photo etched to provide a predetermined minimum surface density of discrete, nucleation sites, each having a conical cross-section tapering to at least a minimum predetermined depth;

a refrigerant having a preselected boiling point disposed in contact with at least the back surface of said chip so as to substantially flood said nucleation sites, said nucleation sites

permitting nucleate boiling of said refrigerant without a temperature overshoot on the initial ascent.

28. A heat transfer system for producing a gaseous product from a liquid, comprising:

a surface having thereon a region which has been photo etched to provide a predetermined minimum surface density of discrete, nucleation sites, each having a conical cross-section tapering to at least a minimum predetermined depth;

a liquid having a preselected boiling point disposed in contact with said surface so as to substantially flood said nucleation sites, said nucleation sites permitting nucleate boiling of said liquid to form said gaseous product without a temperature overshoot on the initial ascent.

29. The heat transfer system of claim 28, wherein said liquid is a cryogenic liquid.

30. The heat transfer system of claim 29, wherein said boiling occurs at a heat transfer coefficient exceeding about  $1\text{W}/\text{cm}^2\text{ }^\circ\text{C}$ .

31. The system of claim 28, wherein said conical cross-

section includes a cavity cone angle,  $\theta$ , which is greater than the liquid contact angle,  $\gamma$ , of said liquid.

32. The system of claim 28, wherein said minimum predetermined depth is greater than about  $3\mu\text{m}$  and a significant portion of said sites have an aspect ratio greater than about .3.

33. The system of claim 28, wherein said nucleation sites include a spacing of less than about  $60\mu\text{m}$ .

37. (New) A method of cooling a surface by nucleate boiling, comprising:

(a) providing a polished, photo etched surface having a predetermined minimum surface density of discrete nucleation sites having a generally conical cross-section tapering to at least a minimum predetermined depth, wherein said nucleation sites comprise spaced reverse-pyramidal cavities lying substantially on the same plane and having a first cross-sectional dimension of less than about  $10\mu\text{m}$ , and a spacing of less than about  $20\mu\text{m}$ ;

(b) immersing said surface in a refrigerant having a liquid contact angle of no greater than about  $5^\circ$  and a preselected boiling point, said nucleation sites become substantially flooded with said refrigerant; and

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(c) causing said surface to heat up to a temperature of at least said preselected boiling point, said heating initiating nucleate boiling of said refrigerant without a reversal of trend.